Applied Environmental Microbiology

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Lecture – 15
Functional Diversity of Bacteria III

Dear students, in the previous lecture I talked about functional diversity of microorganisms that oxidize or reduce nitrogenous and sulfurous compounds; along with some conversation on phototrophs that store or do not store sulfur. And as promised in this lecture we are going to talk about other chemotrophs; other than phototrophs and other than the ones that process sulfur or a nitrogenous compound. And including the ones that are interesting ones such as magnetic microbes and we will deal with the remaining diversity in functions when it comes to bacteria.

So, let us start first with dissimilative iron reducing bacteria. Now even though it says here iron reducing bacteria the important thing to note is that there this belongs to a class of bacteria that reduce metals or metalloids. And here is a beauty we have noticed that microbes that can reduce a certain metal can also reduce other metals. So, this is not very specific generally only to iron reduction.

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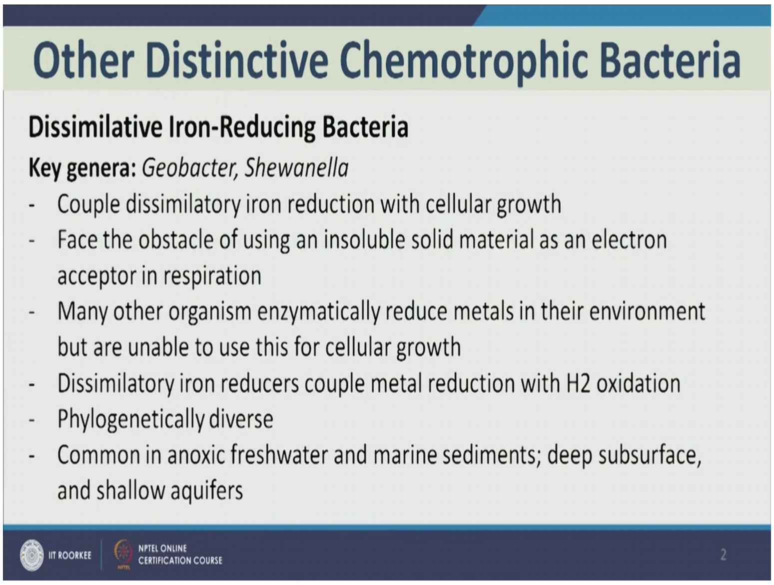

And this is one of the challenges in generating or designing a biomarker for iron reducing bacteria that iron reducing bacteria do not have very specific enzymes most of the enzymes can also reduce other similar metals or metalloids.

And then the word here dissimilative we have talked about it before this implies that the iron reduction is dissimilatory. So, once iron is reduced it is not incorporated in the cell body of the microbe the key genera are Geobacter and Shewanella. I must have you hear the little story about Geobacter it was first discovered by a very famous scientist Doctor Derek Lovely in Massachusetts and this discovery along with many others shot him up to fame. And he is now one of the Stalwarts of geo biogeochemistry, which is biology of earth along with its interactions and chemistry and there is a lot of career prospects and applied environmental microbiology my dear students.

So, do not be disheartened by people who say microbiology only for researchers for example, this Doctor Derek Lovely is has been one of the richest persons in Massachusetts states in USA; even richer than the governor of Massachusetts. Only by his research in applied environmental microbiology. So, let us look at dissimilative to iron reducing bacteria, so the key genera are Geobacter and Shewanella and they coupled dissimilatory iron reduction with cellular growth.

So, what it is saying is that; as they reduce iron they take their energy; to grow the cells they face the obstacle of using an insoluble solid material as an electron acceptor in respiration most of the microbes. They actually need to bring in the electron acceptor into their bodies and that is where the respiration happens. However, iron as you have noted is not soluble in water and it is solid and many a times it exists like a metal.

So, it becomes challenging for microbe on how they are going to reduce iron. And they have come up with a very interesting many very diverse range of interesting approaches to using this insoluble solid material as electron acceptor. What they do is; they externally reduce the metal and they take the electrons either directly into their cell there is one Geobacter that does that or they couple it with metal reduction with hydrogen oxidation.

So, as iron is getting reduced hydrogen is getting oxidized and remember hydrogen lots to get oxidized. And then that energy from hydrogen oxygen is tapped by the energy carriers energy molecules and brought into the cell. So, a many other organisms enzymatically reduce metals in their environment, but are unable to use this for cellular growth. Now, this is very important there are other microbes that whose enzymes automatically reduce iron; automatically reduce other metals such as arsenic and uranium, but they do not use that energy they cannot tap into that energy for cellular growth.

So, this is how iron reducing bacteria are distinct from those microbes that can reduce iron or that can reduce other metals. So, if you cannot tap into a reduction of metal as energy source; you are not a material reducing bacteria you reduce it by default quite passively without any benefit from that process. As I mentioned before dissimilatory iron reduces couple metal reduction with hydrogen oxidation. So, as to bring the energy inside the body inside the cell and they are phylogenetically very diverse.

So, remember this means they are found in different phyla and genetically they are very diverse, but functionally note they are all very similar. So, they are under the same functional category, but genetically they are very diverse, they are common in anoxic freshwater and marine sediments deep subsurface and shallow aquifers and the little work that I have done with iron a reduction was in sediments of a shallow aquifers.

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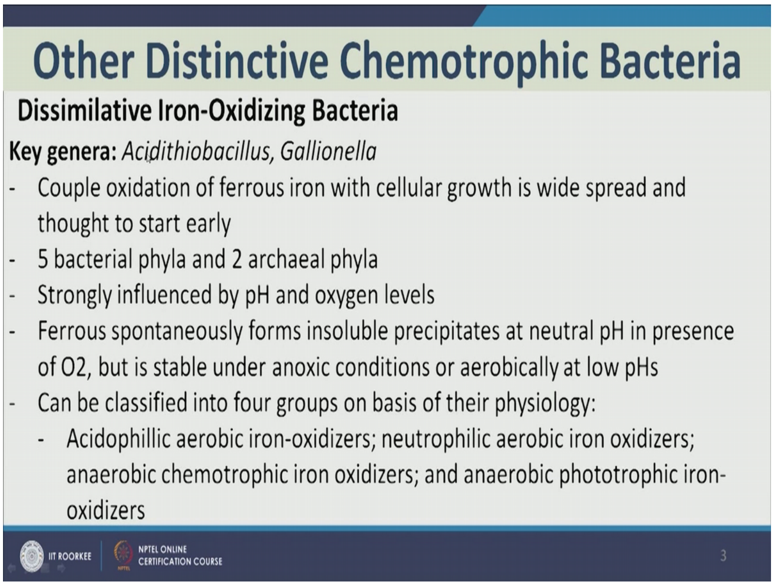

So, the iron can be reduced it can also be oxidized; so dissimilatory or dissimulative iron oxidizing bacteria the key genera are acidithiobacillus and gallionella. They are found within 5 bacterial phyla and 2 archaeal phyla. So, these are just key genera they are many more about key genera; it implies if you hear these gallionella are an oxidizing bacteria, it should bring about what they do is they couple oxidation of ferrous iron with cellular growth. And they are believed to have been one of the first metabolic pathways when a life was evolving on earth they are strongly influenced by pH in oxygen level.

So, they are very sensitive to oxygen you can imagine why if oxygen is present with ferrous iron and the pH is right. Then the oxygen will chemically oxidize, it then not allow the iron oxidizing bacteria to gain that energy trap into that energy for cellular growth and sustenance.

So, this is ferrous spontaneously forms by spontaneously we mean chemically. So, the energy Gibbs free energy drives the chemical reaction and it forms insoluble precipitates of ferric; at neutral pH in presence of oxygen. But if there is no oxygen, then it is stable and iron oxidizing bacteria can do their job sorry or if oxygen is present in the pH should be really low for ferrous to be stable and iron oxidizing bacteria to be able to do their job.

Now look here; so, aerobic low pH where can we have this; in one of the previous lectures; I mentioned about acid mine drainage. So, when we are mining they are exposing these metals to oxygen that have not been exposed to oxygen long time.

So, they are in a reduced form; so let us say I read ferrous instead of ferric and the sulfur in them. If let us say it is ferrous pyrite, if it has get if it is oxidized to sulfate; it will produce sulfuric acid and then the pH will drop. So, now we have low pH and we have aerobic conditions and in this case iron oxidizing bacteria can kick in and what we generate is beautiful colors in acid mine; drainage reverse that and surface water that is affected by acid mine drainage.

A iron oxidizing bacteria can be classified into 4 groups on basis of their physiology. So, they can be acidophilus aerobic iron oxidizers which is talked about them. In fact, if it has to be aerobic they have to be acidophilic otherwise the chemistry will drive the iron oxidation neutrophilic aerobic iron oxidizes very rare anaerobic chemotrophic iron oxidizers and anaerobic phototrophic iron oxidizers.

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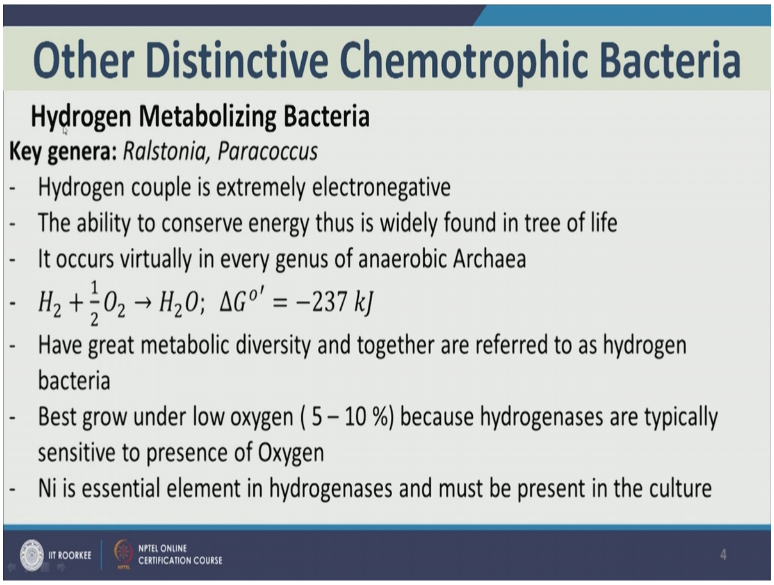

Let other kind of distinct chemotrophic bacteria we want to talk about a hydrogen metabolizing bacteria. So, the key genera are Ralstonia and Paracoccus; now notice here hydrogen metabolizing bacteria you can imagine they are oxidizing hydrogen because hydrogen is extremely electronegative. What it means is that it wants to give electrons away on the other end we have oxygen which is extremely electro positive. And the ability to conserve energy in this way using hydrogen is found widely entry of life; what it is implying is that these are phylogenetically very diverse.

So, they are not just limited to Ralstonia and Paracoccus, but they are found in many many different types of microbes many different phyla. It occurs virtually in every genus of anaerobic Archaea; they are phylogenetically so diverse if we map a Archaea I need point out the an Archaea sorry anaerobic Archaea in almost every genus and genus is pretty fine. We will find hydrogen metabolizing bacteria the equation looks like this hydrogen reacts with oxygen forms water and we have a delta G prime naught of minus 237 kilo joule which is pretty substantial; they have great metabolic diversity.

Now, look at this beauty not only do they have great phylogenetic diversity, but they have great metabolic diversity; obvious question should be all of them are metabolizing hydrogen, then how come they have great metabolic diversity. Well, if we look into different kinds of hydrogen bacteria that is who metabolize hydrogen; we know that they can couple up with different kinds of electron acceptors.

And it is not necessarily always aerobic and in that sense they have a very diverse metabolism and collectively they are referred to as hydrogen bacteria; the best grow under low oxygen. So, micro aerofoils right for 10 percent and why because like nitrogen is their major enzyme hydrogen is sensitive to presence of oxygen.

So, less oxygen is better for them they are not as sensitive as nitrogen is, but they are pretty sensitive they need nickel. So, if you are growing hydrogen bacteria in lab; your media should have nickel in it and because the hydrogen is an essential component of hydrogen is nickel. So, next kind of bacteria we want to talk about is methanotrophic and methylophic; now both bacteria are very very common in subsurface when you go wait beneath the earth and try exploring the soil microbial community there.

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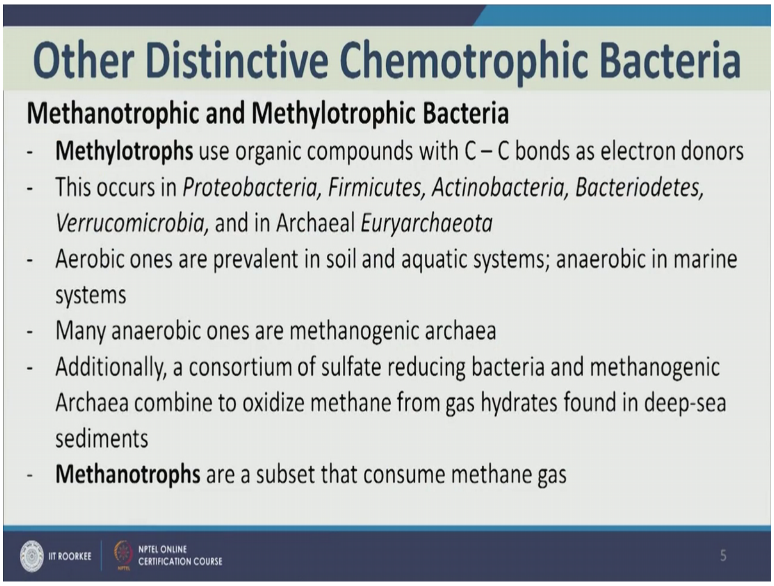

And usually its oil and natural gas companies that are more interested in this, but it is very interesting domain for avenue for research and applied environmental microbiology anyway.

So, methylotrophy; so, they use compounds that have two carbon remember methane one carbon, but when we are talking about methyl. So, this carbon is attached with some other carbon; so, we have two carbon bonds and that is what serves as electron donors. Again they are pretty diverse phylogenetically, now these are very big broad phylum proteobacteria. For example, has is in itself phylogenetically very diverse; for example, alpha, beta, delta, gamma, epsilon, proteobacteria are very different from each other and within themselves there were a dell lot of differences. Firmicutes, again very diverse Actinobacteria, Bacteriodetes when you Verrucomicrobia and Archaeal Euryarchaeota.

So, very diverse phylogenetically the ones that are aerobic they prevent prevalent in soil and aquatic system; obviously, the ones that are anaerobic would be found way in down deep in the oceans and seas. So, in marine systems many anaerobic ones are methanogenic archaea; this is very interesting. So, methylotrophs who use a double 2 C chemicals as the source of electron; produce methane. So, they use this a source of electron and they reduce it to methane. So, two carbon compound becomes one carbon methane and energy is generated their energy is stopped in.

So, additionally sometimes sulfur reducing bacteria in methanogenic Archaea combine to oxidize methane from gas hydrate found in deep sea sediments. This is very different thing happening and this is also a recent discovery actually. We know now that methanogenic Archaea the ones that produce methane and there is already plenty of methane present in gas hydrate there was a couple up with the sulfate reducing bacteria.

So, they will be meet the sulfate oxidation of methane and energy will be generated and this energy is used by both microbes to survive. And because otherwise methane in this circumstance sulfate you are reduce reduction and methane oxidation, the delta G and the energy barrier together are not feasible enough for this reaction to happen unless they make this consortium.

Methanotrophs are a subset that consume methane gas; so, if they only consume methane gas and not other carbon sources that fall under methyltrophy, then they are called as methanotrophs.

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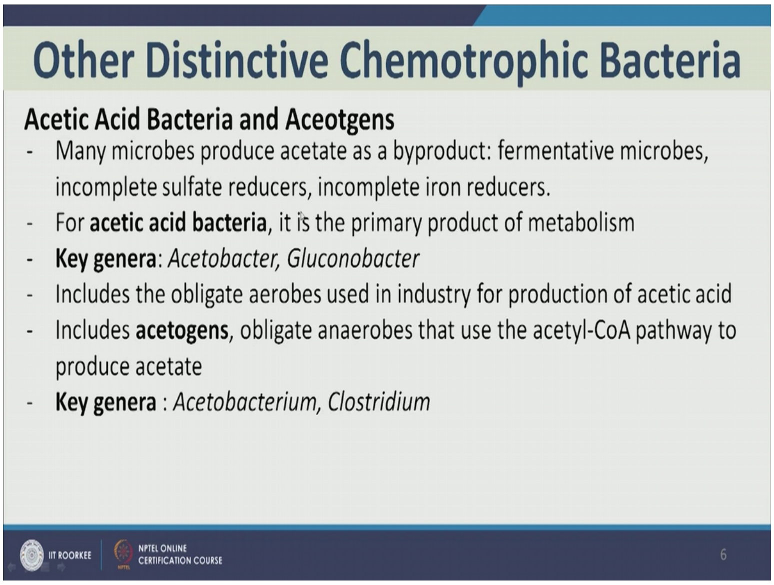

Remember trophy means eat; what you eat and methane you eat methane. The other kind of distinctive chemotrophic bacteria; that we are interested in our acetic acid bacteria and acetogens. Now many microbes what they do is; they produce acetate as a byproduct.

So, if there is an incomplete sulfate reduction happening, there is incomplete added reduction happening or often in case of fermentation will have acetate as a byproduct and then nobody wants to use acetate. So, microbes that create acetic acid as their by product or sometimes as the primary product of metabolism are called as acetic acid bacteria; they usually fall under Acetobacter and Gluconobacter.

So, look at even the names of these microbes will give you an idea what they are about Acetobacter. They usually include obligate aerobes and these are used for industrial production of acetic acid and they also include acetogens which obligate anaerobes.

So, they look here even acetic acid bacteria and acetogens are metabolically very diverse, they can be obligate aerobes, they can be obligate anaerobes; cannot survive without oxygen; cannot survive with oxygen. And they use acetyl coenzyme a pathway to produce acetate, in this case a key genera would be Acetobacterium look here; again aceto and clostridium; most clostridium FYI are anaerobic microbes.

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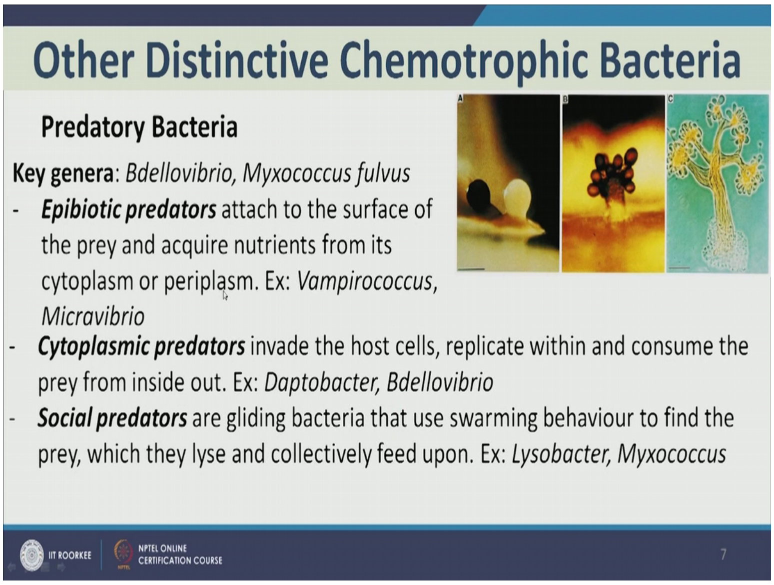

Now, this is where things get very interesting for you I hope; now we are going to talk about predatory bacteria. So, far we have talked about bacteria who actually utilize the chemicals around in the environment and the light, the energy sources in the environment and they tap into this to drive biochemical reactions; we should give them energy and we should give them carbon.

But now we have microbes that actually prey and live off other microbes. So, this is hunting and predator prey model for microbes; let us look into it. The first we are going to talk about predatory bacteria which literally go and attack a bacteria; kill it and eat it. Now there are three kinds of predatory bacteria; first is epi biotic bacteria, what they do is they attach to the surface of the prey. So, they come in the attached to it like leeches attached to higher order of life like; if you get a leech out the blood of your body.

Similarly, epi biotic predators attached to the body; they acquire nutrients from the cytoplasm or from the periplasm. So, if you remember in many microbes we have cellular membrane then we have periplasmic membrane. And between cellular membrane and periplasmic membrane; we have periplasm. So, sometimes they do not just stay outside the cell wall, but they enter it and they stay in the periplasm and they suck out all the nutrients from cytoplasm; eventually they slice the cell, they kill it and in that process they have multiplied, they have grown; these are epi biotics.

So, epi means outside bio means life; so they stay on the outside of life. They will stay on the cellular membrane, also the cell wall or in some cases within periplasm, but still they are outside the cell. Then we have cytoplasmic predators, they actually go inside and live inside the cell. So, they invade the host cells and they replicate within they consume the prey literally from inside out. Some examples are daptobacter and bdellovibrio; we will be talking about bdellovibrio little bit more in detail. And I hope this interests you epibiotic predator one of the example is vampirococcus very vampire like in nature.

The mythical vampire bites the prey and then sucks the blood out; which is what epibiotic predators do. Then we have social predators, these are really cool predators they cool in sense, they have very complex and very complicated lifestyle and life cycle. They glide, they move in swamps and when we talk about moving in swarms; it appears as if all these unicellular microbes, when they move together in a herd or in a swarm they act as if they are one single organism.

So, even then this implies they have really good communication with each other and in microbes when they communicate with each other please note it is called as quorum sensing. So, they are sensing how many people are present? How many of them are from my community, my kind of bacteria and what is going on? So, they can communicate with each other using these chemicals, this is called quorum sensing.

So, they use this quorum sensing in this swarming behaviour which is moving in herds together as if it is one singular organism to find out prey. And once let us say one of the social predator finds out; this is a prey here the entire swarm will gather around it and then they release enzymes that will lies the prey and then they collectively feed off the prey.

The example are lysobacter and lysobacter as the name suggests it lyses the other cells and my so myxococcus and we will be talking about myxococcus a little bit more in detail.

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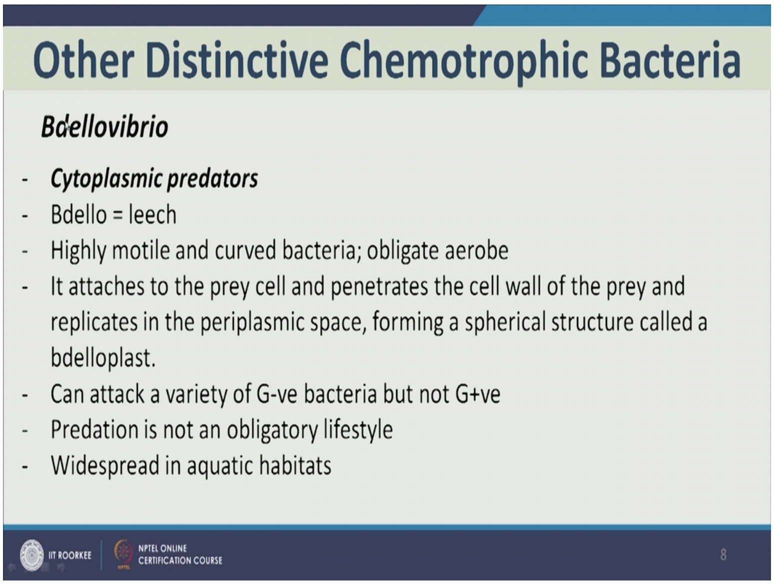

So, let us first talk about Bdellovibrio; these are cytoplasmic predators which means the epi biotic predators. They want to leach off the; I am sorry they are cytoplasmic predators which implies that they actually eat the cell inside out; now Bdello means leech.

So, the name suggests like a leech vibrio; they are highly motile and they are curved bacteria. So, they are curved in shape they highly motile they move really fast, they obligate aerobes, they need oxygen. They attach to the prey cell, they penetrate the cell wall of the prey, they replicate in the periplasmic space forming a spherical structure called bdelloplast.

And they can attack gram negative bacteria by and not gram positive why is that so? You can expect this question in the homework; why it can be only attack gram negative bacteria and not gram positive? Now, here is a cool thing for bdellovibrio predation is not an obligatory lifestyle, they can actually act like a chemotroph; they do not need to hunt and invade a cell and the widespread in aquatic habitats.

So, let us take a while and let us look at the lifecycle of bdellovibrio; when it has chosen a predatory lifestyle. So, let us say this is a cell; the prey and usually bdello bacteria are very small compared to their preys.

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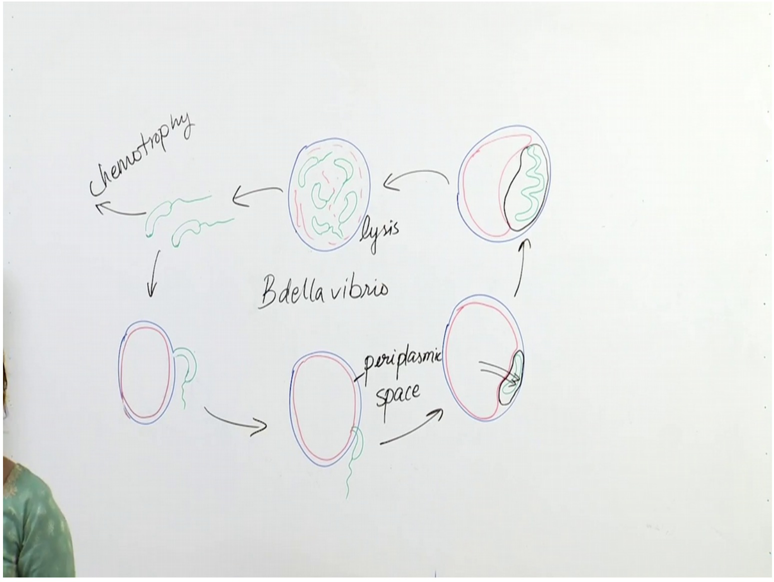

And as mentioned they are curved and they highly motile, they have this web like structure that more helps in move very fast.

So, they will attach to the outer membrane of the cell and then the next step is they will enter the periplasmic space. So, this is the periplasmic space; they will enter the periplasmic space. So, here they have entered and they will start leeching off the cytoplasm; they start consuming the cytoplasm.

And what they will do is eventually they form a bdelloblast around it. So, they make us different pocket here. So, now within the periplasmic space we have two things; we have cytoplasm covered by cellular membrane and we have bdellovibrio covered by bdelloblast and then here also there will be a bdelloblast.

So, as it leeches off more and more nutrients from cytoplasm; it elongates, it grows longer. So, you can see the bdellovibrio has grown so long and the next step would be it leaches of everything it can from the cytoplasm. And then it breaks into new bdellovibrio and the cytoplasm is gone and then the next; these are lysis step; internal lysis of cell.

And the next thing we know that a cell has disappeared and we are left with new bdellovibrio. Now, it can choose to go for chemotrophy or depending on the situation it can choose a predatory lifestyle.

The next example is social predator Myxobacteria.

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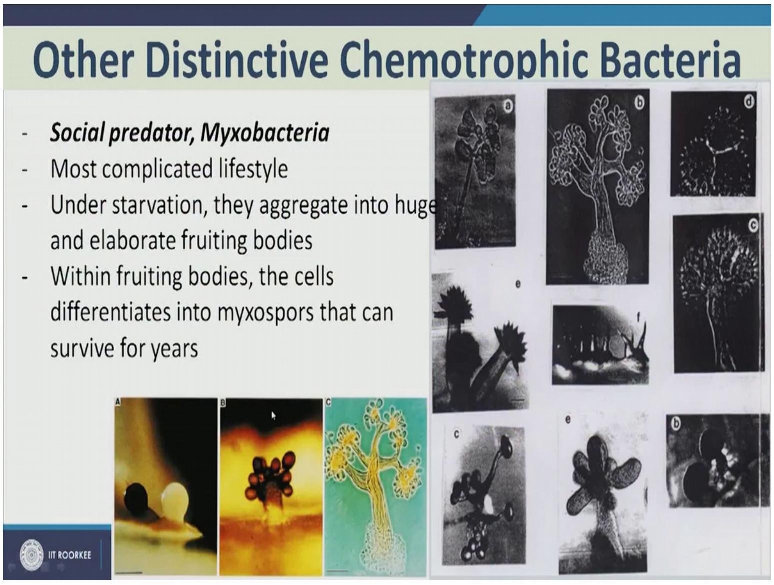

Now, this has a very complicated lifestyle; one of the most complicated lifestyle among all bacteria. When they are under starvation, which is when they do not have good food or in good nutrients available; they aggregate into this huge elaborate fruiting body. So, when they aggregate deform heaps of myxobacteria and then from these heaps emerge the elaborate fruiting bodies. So, here notice let us look at the picture these are fruiting bodies if you can look at the right panel.

So, initially a heap is formed it looks like a heap of mud of myxobacteria. And then from them this elaborate fruiting bodies emerge and within them they divide into myxospors. So, these are myxospors here and these can survive for years under really bad conditions. So, they are not as stable as spores of bacteria, but they are pretty spores; pretty stable. Now, let us talk about social predators and these are myxobacteria actually example of social predator; vegetatives their vegetative cells are simple and non flagellated.

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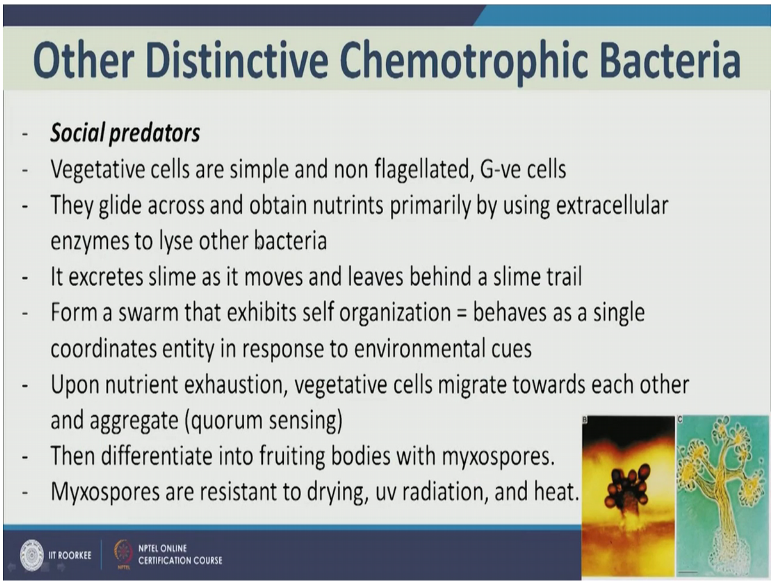

So, if you look at myxobacteria here; it is non flagellated and it is pretty simple, they glide across in swarms. So, remember the swarming behaviour and they obtain neutrons primarily by using extracellular enzyme to lyse other bacteria. It excretes slimes as it moves; so when these social predators they move they leave a slime trail. So, if you look at us some snail moving; you can see a slight trail of wetness that follows it. So, they leave a slime trail they form a swarm that exhibits self organization which is really need. So, they behave as a single coordinated entity in response to environmental cues and people believe that this is the origin of multi cellular life forms.

When nutrients have exhausted; they are in a scarcity or and then what will happen is vegetative cells will move towards each other. So, this is where they use the quorum sensing; they aggregate they perform heaps and then this from these heaps emerge fruiting bodies. So, these fruiting bodies they form microspores; so, you see here they are beginning to form heaps and here they have made a heap here and from heap emerge this fruiting body and fruiting body has specialized into myxospores.

Now, these myxospores they are resistant to drying UV and heat, but not as resistant as in dispose of some other bacteria. And from here when the nutrients are available again, when life is more sustainable again they can fruit and form more of the bacteria.

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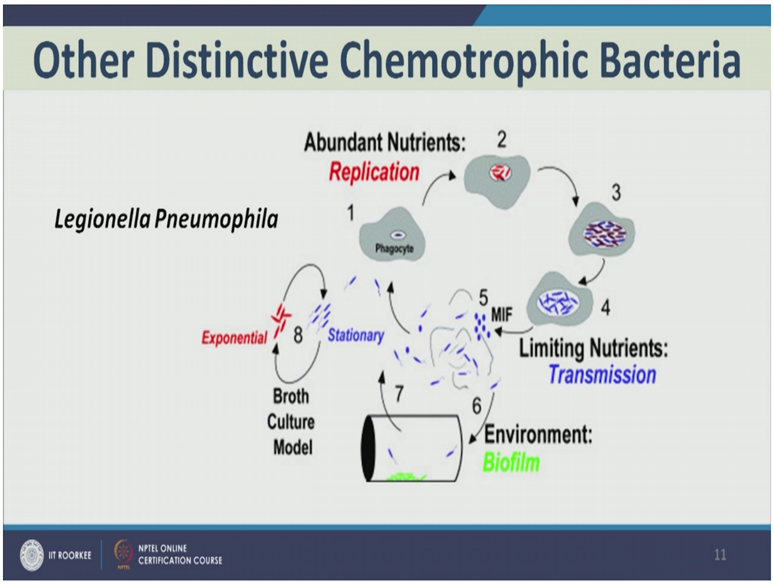

The other example that I want to talk about this Legionella Pneumophila because it is very relevant when it comes to public health and Legionella Pneumophila is an issue for environmental engineers and environmental scientists. Because, we notice that in a water systems let us say our indoor plumbing environment.

Depending on the water flow, depending on the water chemistry, depending on the nutrients that we are supplying or that are present in the water; the conditions might be ideal for Legionella Pneumophila to grow inner biofilms of our drinking water system. Now Legionella Pneumophila is typically requires warm temperatures; so its it either has to be hot climate like India or other equatorial tropical places or it has to be a hot environment such as in water heaters.

So, what Legionella Pneumophila will do is it enters into an amoeba. So, it enters; so, this is an environment and this is Legionella Pneumophila it has entered here. And it can either stay in the proterozoic of free floating form and go back to the drinking water or it can invade the biofilms.

Once it has invaded the biofilm, what it does is; it is eaten up by an amoeba. So, the if there is an amoeba present; the right amoeba present in the biofilm it will eat the Legionella Pneumophila, but it is not able to destroy this bacteria. And then this bacteria it will eat the amoeba from inside out. So, what it does is; it replicates within the bacteria it consumes its nutrients until it is. So, strong that it will lysed the amoeba and then we have multiple copies of legionella spread.

So, this is a very important diagram and I want you to be very clear about this. Again in this when we grow Legionella in lab, we notice there are two growth phase exponential and stationary and both morphologically are slightly distinct.

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Now this brings us to morphological diversity of bacteria. So, this is a picture that I showed you in one of the first lectures and this is from human gut. So, my scientist took human gut microbes and they tried seeing it under microscope and this is definitely a false color image.

So, they were colored later initially microscopes are at black and white, but notice if within one environment we have such diversity in morphology. We have big rounds, we have here, elongated cylinders, we have rods and we have made a different colors, but we also have coccus, spheres, balls; some of them stick, some of them do not and we have this dumbbell shape kind of microbe. And then we do not see many about in human gut, we also have some filamentous.

So, we notice even in a very small snapshot; now imagine this is a very small part of human gut. So, in a very small snapshot we have quite some diversity of morphology and we know again from one of the first few lectures.

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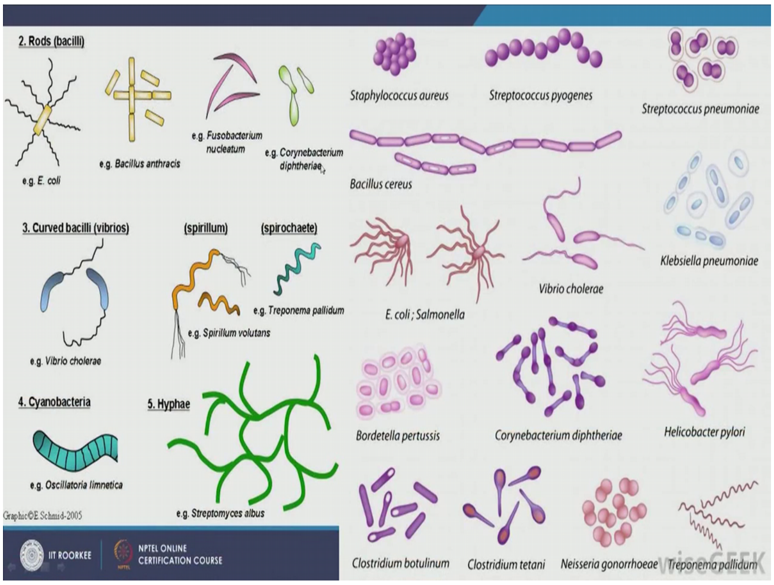

That there is immense diversity in morphology and there is a reason behind this diversity; because each of these decides how suitable microbe is for living in the environment.

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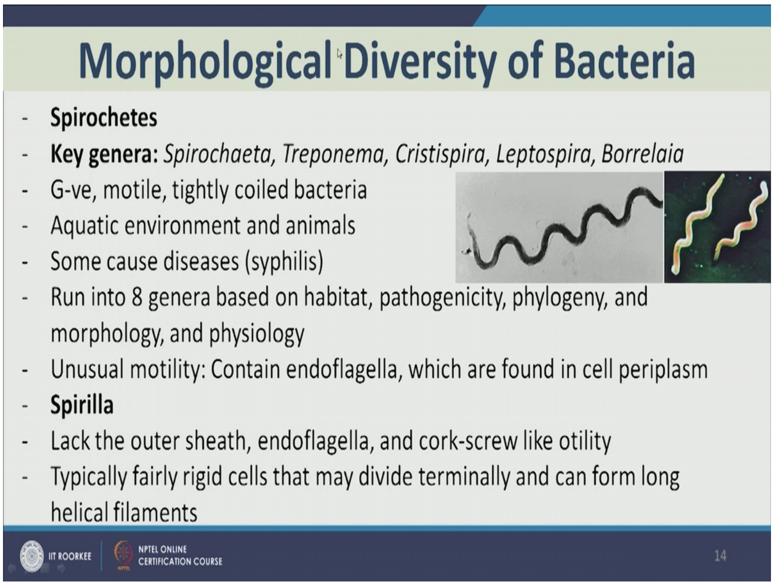

So, depending on morphological diversity of bacteria; let us go through them. First is spirochetes; this is very interesting bacteria because it moves in a very different way; its motility is not driven by your typical ATP synthesis kind of motor.

In fact, these are gram negative and they tightly coiled bacteria and they contain end of flagella. So, they do have flagella the web like structures, but they are inside them and they have a common sheath. Now this endoflagella they when they move in the same direction; the micro moves in the other direction thus creating a torque and this torque propels the spirochete is outside. They run into 8 genera based on habitat the pathogenicity, phylogeny, morphology and physiology.

Now, here I mentioned pathogenicity spirochetes some of them cause diseases and one of them causes syphilis which is sexually transmitted disease in humans. And then there is another microbe called spirilla, which also looks like a spiral; like a spring and it is often confused to be a spiral sheaths. But there is a big difference between the two; they do not have an outer sheath and they do not have endoflagella and they do not have this cork-screw like motility.

And I will talk about what this cork-screw motility is; spirilla unlike spirochetes are typically rigid cells and they divide terminally and they can form long helical filaments.

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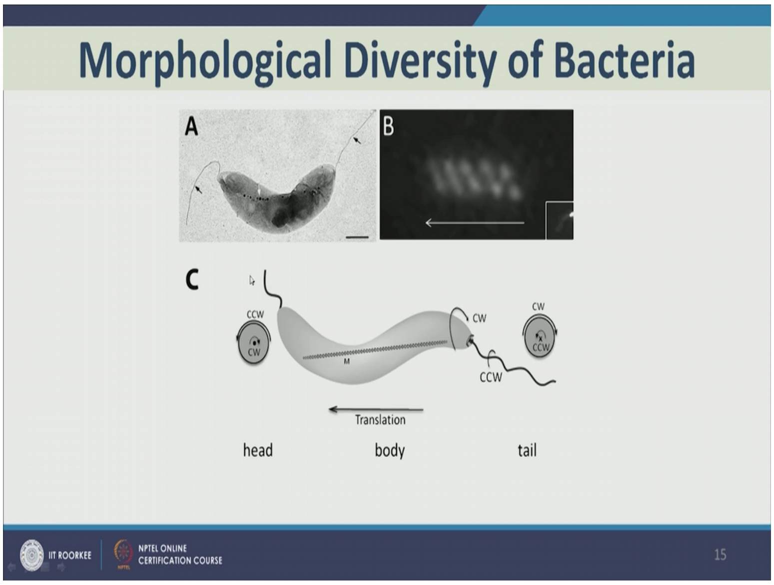

So, let us look into the movement of spirochetes.

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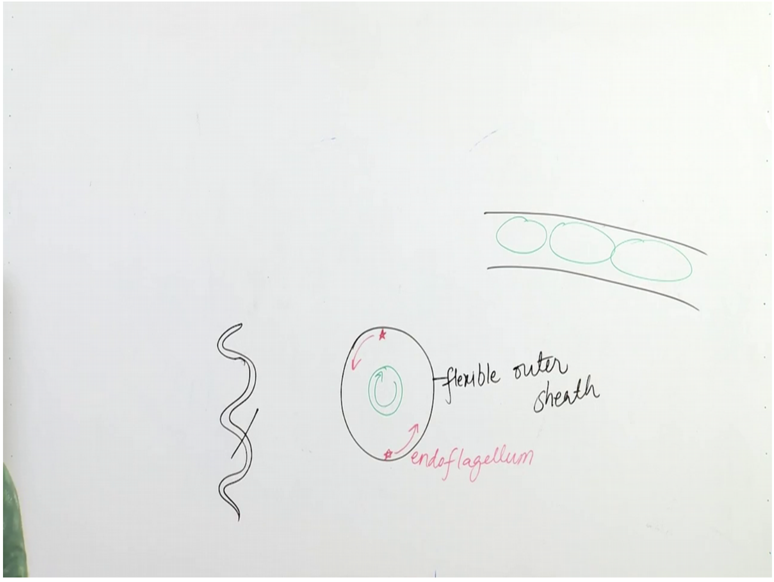

Students, so this is a cartoon of spirochete, a typical spirochete; it is very hard to draw a spiral. So, I have just drawn a curvy model of a microbe and I hope you can imagine in your mind that this is actually a spiral microbe. And if we look at it; if we cut off here like this radially, we will see something like this.

So, its cross section would look something like this, there is an outer sheath which is black in color and rest are visible from outside. And this is a flexible outer sheath, inside is the actual cellular membrane which is quite rigid actually.

And here on the outer sheath; you will notice at polar ends we have endoflagellum. So, these are in endo; so they inside the cell they are inside the outer sheath and they are used for motility; for movement. Now, then in the enodoflagellum move and in the same direction they create a motion in this direction; in this flexible outer sheath. At the same time the inner sheath it moves in the opposite direction and thus they create a torque and this torque is what allows it to move in a cork screw like motion.

So, a cork screw; you screw the screw nails inside the a wood or inside the wall; it moves like this and it goes in and this is how they go in and this and unlike the other spirala that we talked about; they are the only bacteria who can have this cork screw like motion. Now, next are morphologically diverse again budding bacteria the key genera are hyphomicrobium and coulobacteria.

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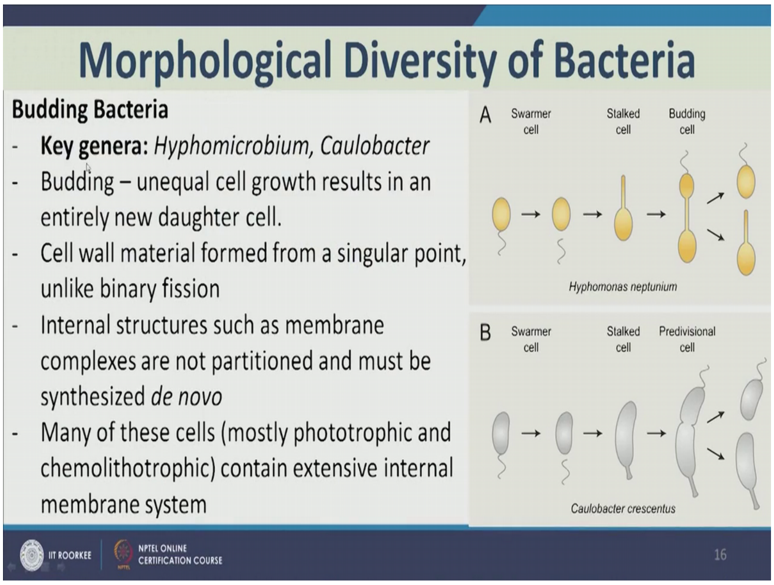

Now, budding bacteria are those bacteria that when they divide they do not undergo the typical binary fission.

So, if you remember we learned that in typical binary fission; we have cells and they produce two of everything and then they divide into two equal daughter cells. But in budding we have unequal cell growth; so, we can say that the parent stays intact and a daughter buds out.

The other difference between budding and binary fission is that in binary fission we have two of all enzymes two of the genetic material, but in budding with the daughter cell it has to de novo synthesize some enzymes. And this is one of the advantage for budding microbes because they can; it is easier to de novo synthesize certain complex enzymes than to make two of them and separate them.

And the another difference is the cell wall material in budding bacteria here; budding bacteria are formed from a singular point. But in cell division in binary fission the entire cell membrane participates into it; internal structures such as membrane complexes are not partitioned. So, remember membrane complexes in cytoplasma membrane may not partitioned here and must be synthesized de novo. And most of them are phototrophic, chemolithotropic and they contain extensive internal membrane system. And because they have such extensive internal membrane system; it is very hard to replicate it and make body a break into two daughter cells.

So, they prefer budding and then the new daughter cell will produce its own extensive internal membrane system de novo.

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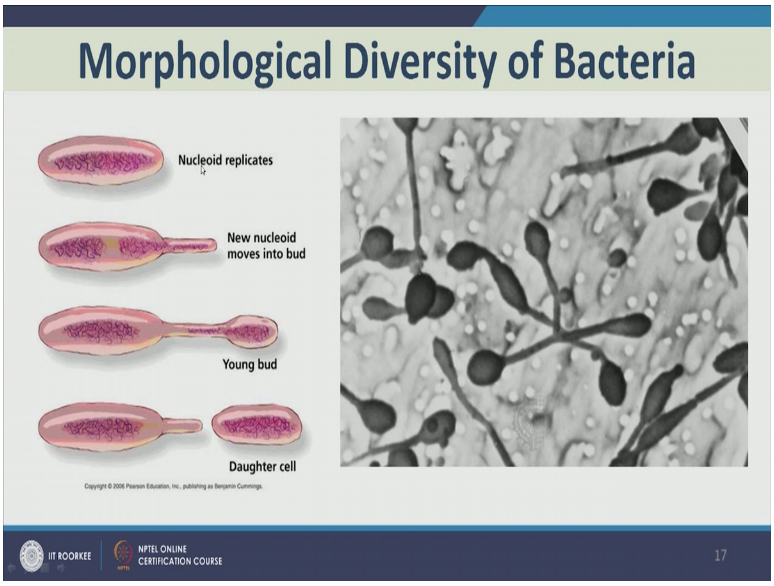

So, this is another picture of budding bacteria; notice from one pointer cellular membrane should sound new nucleoid to new. So, this genetic material has replicated into two; the genetic material moves in here, the new nucleoid moves into the bud; this is a young bud. And then nuclear material is ready and it separates; so, it still does not have the complex internal membrane proteins that this this has, but it will it has enough information to generate them to know.

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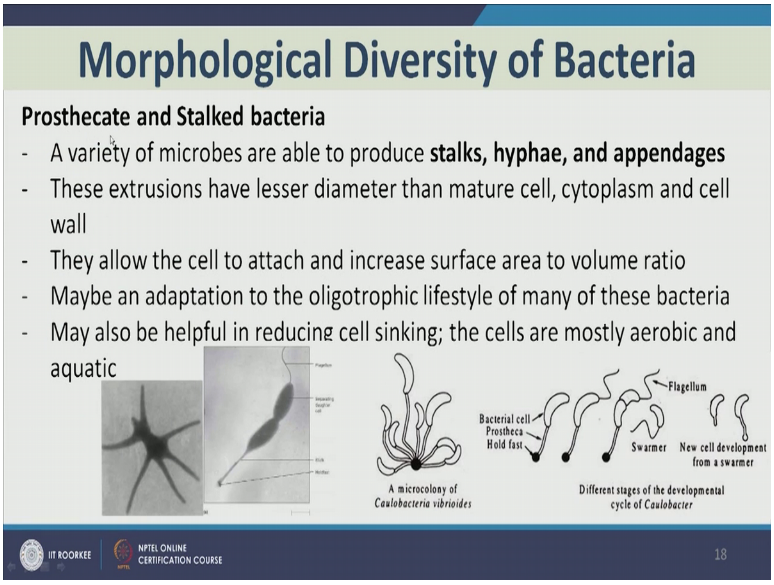

Next we have prosthecate and stalked bacteria; so, there are certain bacteria that can produce stalks hyphae appendages that help it to attach; these extrusions are unique because they have smaller diameter. Then the main body of the cell, but they still have cytoplasm and cell wall.

So, there is another advantage because they still have the cytoplasm and the cellular membrane, they increase the surface area to volume ratio. They allow cell to attach an increased surface area to volume ratio; they may be in adaptation to oligotrophic lifestyle of many of these bacteria.

So, we will see this more in the drinking water systems when attachment is required and also when they will not be increase the surface area to volume ratio; so, that they can have more surface for nutrients to come in.

And they may also be helpful for reducing cell sinking; if we increase the surface then the upward thrust of the water will be more. So, this is important when the cells are aerobic and aquatic if they need to stay afloat, if they will sink down then they will go an anaerobic zones; and these are other example pictures showing the same thing.

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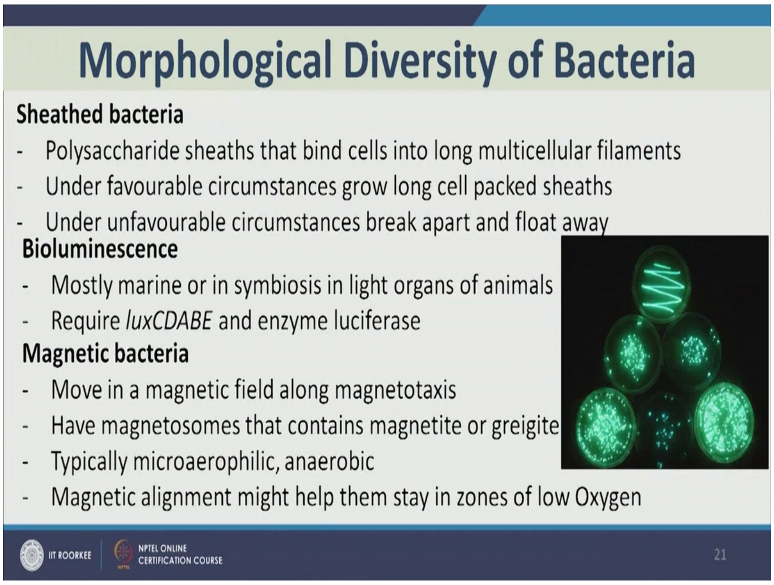

Now, in sheath bacteria we have of these very interesting bacteria; they are cells that grow and one terminal they form long filaments and multicellular filaments and they have one outer sheath.

So, if you look at under microscope you will see one long cylinder, but inside these cylinders there are multiple cells. So, it will look something like this; so, we have one long sheath and inside these sheaths we have multiple cells. Under favorable circumstances, they will grow long cell patches under unfavorable favorable circumstances; they break away and they disperse to find more suitable environment.

Now bioluminescence; this is really cool look at this picture, these microbes are glowing in the dark. And most marine; deep marine organisms require this bioluminescence, the other kind of animals who require bioluminescence are animals who are deep sea animals.

So, they need light; they will have no light source to see, to be visual and what they have in their light organs like what we have eyes is our light organ; they have this bioluminescent bacteria that glow. And how they glow? They use this gene; log cdabe this gene incodes for the enzyme that is required for glowing in dark and we have exploited these luciferase were creating some marvelous technologies in microbiology.

Then we have magnetic bacteria; these are really need, they have these magnetosomes which are cell parts that contain magnetite or greigite both are forms of iron that are magnetic in nature. And because of this; they tend to move and align themselves along the north south pole of earth. And there is a hypothesis that this alignment with north South Pole of earth allows them to stay in the zones that are low oxygen.

So, it is like a compass that directs them where to go where not to go; because their body automatically will align the north south direction. And if there is some magnetic mineral around, it will get attached to it. They are typically micro aerophilic and anaerobic they do not like oxygen.

So, this is all for today and in the next lecture we will continue and we will talk about ecological diversity. We will talk about the ecol microbial ecology in different environments and that is all for functional diversity on bacteria.

Thank you very much.